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Risk assessment of human pathogenic *Yersinia enterocolitica* in minced meat in Belgium

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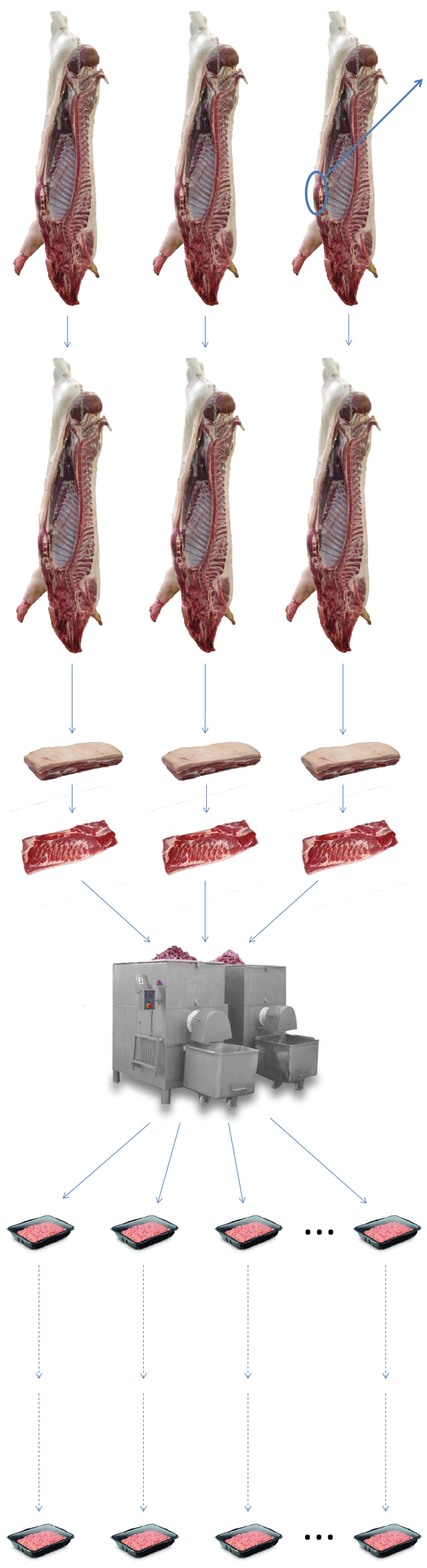
Domestic pigs are the main reservoirs of human pathogenic *Yersinia enterocolitica.* The **consumption of raw minced meat** has been shown an important risk factor for human infections. A **modular process risk model** (MPRM) was used to perform an **exposure assessment** of human pathogenic *Y. enterocolitica* in minced meat produced by industrial meat processing plants in Belgium. The model described the production of minced pork starting from the contamination of pig carcasses with *Y. enterocolitica* at time of slaughter. As no dose response model is available for *Y. enterocolitica* infections in humans, the end point of the assessment was the **proportion of 0.5 kg minced meat packages that contained more than 10^3 *Y. enterocolitica*** at the end of storage (just before raw consumption or preparation). The entire model was simulated with Monte Carlo techniques using @Risk software.

THE BASELINE SCENARIO

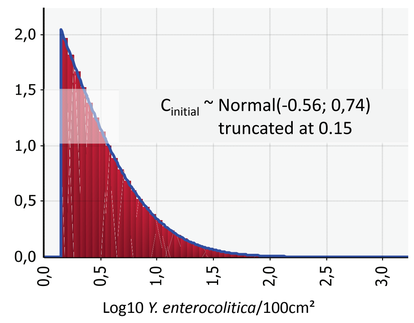
SLAUGHTERHOUSE

MEAT PROCESSING PLANT

CONSUMER - RETAIL



Variable	Description	Value/distribution*
Initial contamination: carcasses after evisceration (sternum)		
$P_{initial}$	Prevalence on pig carcasses	16.39%
$C_{initial}$	Concentration (log_{10}) on positive pig carcasses	

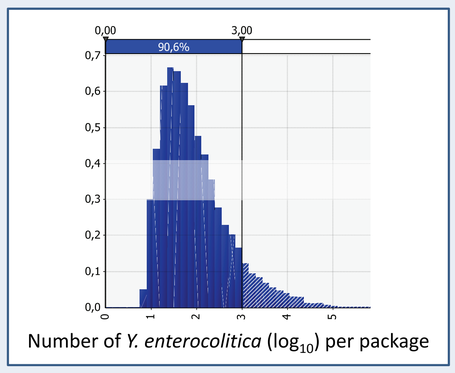


Inactivation during blast chilling		
I_{cc}	Inactivation during blast chilling	0.6 log_{10} CFU
C_{cci}	Concentration on pig carcasses after blast chilling	= $C_{initial}$ - I_{cc}
Growth during 'regular' chilling		
$Time_{ccg}$	Chilling time of carcasses	20 or 68h
$Temp_{ccg}$	Temperature during chilling	4°C
L_{ccg}	Lag phase during carcass chilling	24h
D_{ccg}	Doubling time during chilling	9.978h
N_{ccg}	Number of *Y. enterocolitica* after growth during chilling	$N_{cci} * 2^{(Timeccg-Lccg)/Dccg}$ (if $Time_{ccg} > L_{ccg}$)
C_{ccg}	Concentration of *Y. enterocolitica* on carcasses after chilling	N_{ccg} in log_{10} CFU/cm²
Cutting and derinding		
R_{bd}	Removal	50%
C_{bdr}	Concentration of *Y. enterocolitica* on belly cut after cutting/derinding	$= 10^{Cccg} - 10^{Cccg} * R_{bd}$ (CFU/cm²)
S_{bd}	Surface of belly cut	2000 cm²
N_{bdr}	Number of *Y. enterocolitica* on one belly cut after derinding	Poisson ($C_{bdr} * S_{bd}$)
Mixing and grounding		
W_{batch}	Weight of a batch of minced meat	900 kg
P_b	Proportion of bellies per batch (w:w)	34%
W_b	Weight of a belly cut	7.5 kg
N_{bb}	Number of bellies per batch	$= W_{batch} * P_b / W_b$
N_{pbb}	Number of positive bellies per batch	Binomial (N_{bb}; $P_{initial}$)
N_{batch}	Number of *Y. enterocolitica* in one batch (minced meat mix)	$\sum_{n=1}^{N_{pbb}} N_{bdr}$
Partitioning		
W_{mp}	Weight per minced meat package	0.5 kg
N_{mp}	Number of minced meat packages	$= W_{batch}/W_{mp}$
N_{mpp}	Number of *Y. enterocolitica* in one minced meat package after packaging/partitioning	Binomial(N_{bacth};$1/N_{mp}$)
Growth during storage		
$Temp_{mr}$	Temperature during storage in meat processing plant and at retail	4°C
$Time_{mr}$	Time between packaging and purchase (retail)	48h
μ_{max}	Maximum growth rate	Function of temperature
N_{mrg}	Number of *Y. enterocolitica* in one package of minced meat at time of purchase	= Nmpp * $10^{\mu max * Timemr}$
$Temp_{cons}$	Temperature of home refrigerators	Pert(25% 5; 50% 7; 75% 9)
$Time_{cons}$	Time between purchase and consumption/preparation	Pert(0;1;4) (in days)
N_{mcg}	Number of *Y. enterocolitica* in one minced meat package at the end of storage	= N_{mrg} * $10^{\mu max * Time(cons) * 24h}$

* Data source available upon request

THE BASELINE RESULTS

Using the baseline scenario, the prevalence of *Y. enterocolitica* in minced meat packages was estimated to be 15.4% (≥ 1 cell/package of 0.5 kg). The model estimated that 1.32% of minced meat packages contained more than 10^3 *Y. enterocolitica* at the end of storage.

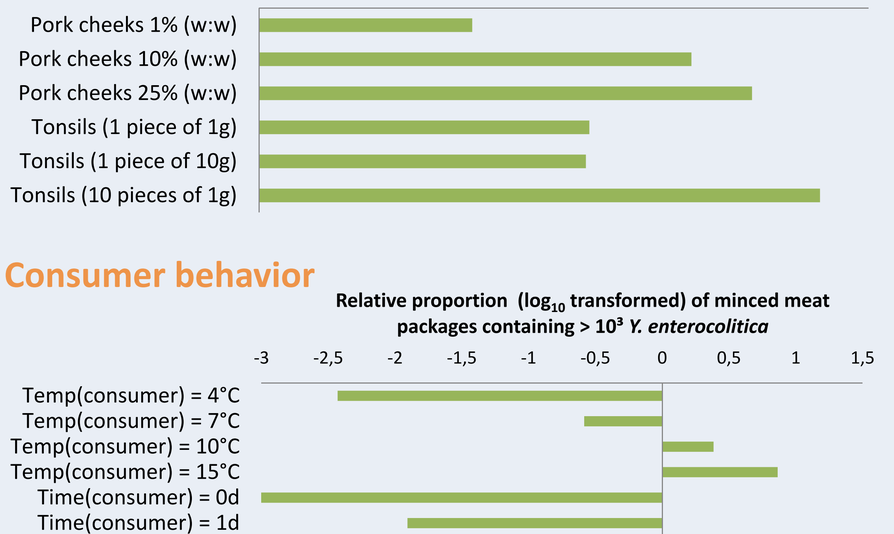


Distribution of *Y. enterocolitica* in POSITIVE minced meat packages at the end of storage (before raw consumption or preparation)

ALTERNATIVE SCENARIOS

To evaluate the effect of alternative scenarios, the value of one or two model parameters was changed and the corresponding end point estimate (proportion of minced meat packages containing > 10^3 *Y. enterocolitica*) was compared to that of the baseline scenario.

Initial contamination

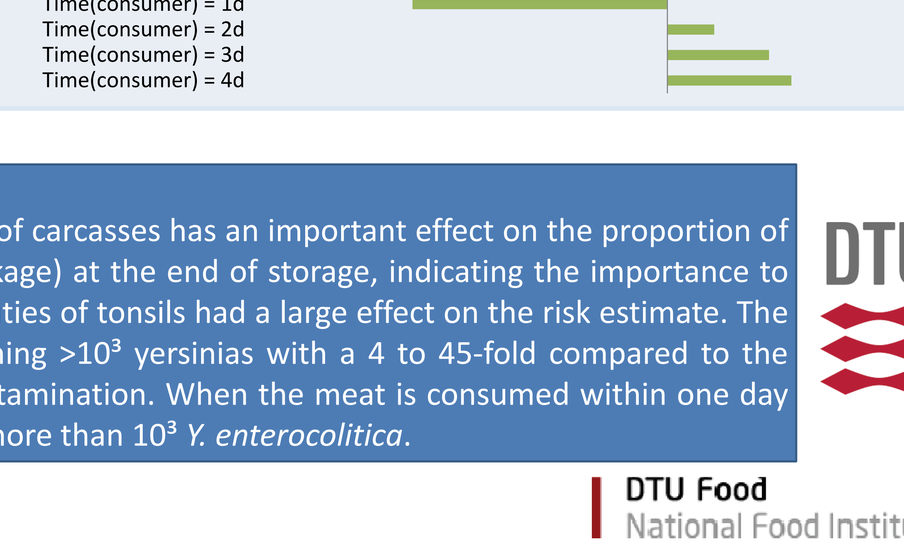


Relative proportion of the end point estimate (minced meat packages containing >10^3 *Y. enterocolitica*) from alternative scenarios compared to the baseline scenario given on a log scale, so "-1" implies a 10-fold reduction. Symbols indicate the change in the alternative scenario compared to the baseline model. Change in concentration: ↓ : mean initial concentration is 0.5 log_{10} lower compared to the baseline model; ↑ : mean initial concentration is 0.5 log_{10} higher compared to the baseline model; = : the mean concentration is -2.56 log_{10} *Y. enterocolitica*/cm² (baseline).

Addition of head meat or tonsils

The inclusion of head meat (pork cheeks) and tonsillar tissue during grinding of a batch of 900 kg was simulated using prevalence and count data of the mandibular region on carcasses before chilling and tonsils of pigs during slaughter, respectively.

Consumer behavior



Conclusions

Comparing alternative scenarios to the baseline model showed that the initial contamination of carcasses has an important effect on the proportion of minced meat packages with high numbers of *Y. enterocolitica* (>10^3 *Y. enterocolitica* per package) at the end of storage, indicating the importance to control the pathogen at slaughterhouse level. The addition of pork cheeks and minimal quantities of tonsils had a large effect on the risk estimate. The addition of these highly contaminated tissues increased the proportion of packages containing >10^3 yersinias with a 4 to 45-fold compared to the baseline model that only assumed the use of pork bellies as a source of *Y. enterocolitica* contamination. When the meat is consumed within one day after purchase, the model predicted that less than 0.001% of minced meat packages contain more than 10^3 *Y. enterocolitica*.

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